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Final Report

Numerical Model Studies of the Martian Mesoscale Circulations

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1) Introduction

This program consiststed of collaborative efforts with M. Segal and R. W. Arritt of Iowa State University and University of Washington tasks by J. E. Tillman. During the first year at UW we completed a comprehensive analysis of high frequency data from the Viking Lander, funded mainly under prior support, that adapted Earth surface layer similarity models to Mars, enhanced them as needed, and estimated a number of key parameters of the Martian planetary boundary layer. These analyses, carried out with colleagues from Denmark, estimated diurnal variation of heat and momentum flux, of stability and the height of the mixed layer for several sols. The results were published in J. Atmos. Science in 1994, and Landberg, Larsen and Tillman, 1995. The knowledge gained and specific aspects of these analyses were used in the the collaborative comparisons with the Segal and Arritt models. Model runs investigated the effects of the surface sensible heat flux on cold air outbreaks in the thin Martian atmosphere, and a paper has been accepted for publication.

A number of model runs were made to estimate the winds during landing at the Mars Pathfinder site and were presented to the Science Advisory Team for site evaluation by Tillman, a team member. Other runs were made to investigate the effect of wind speed on atmospheric temperature in an unsuccessful attempt to explain Tillman's observations of strong inter-annual temperature differences during summer at the Viking Lander 2 site, 48° N. Finally, a component of the Viking Meteorology software that estimated Mars surface temperatures was extracted as a stand alone module from Tillman's Prime computer, moved to the Unix workstations, and checked out. Reports, talks and publications are listed at the end.

2) Investigations

1.0 Daytime surface sensible heat flux and Martian cold air outbreak dissipation

We provided data and analyses for Segal and Arritt's modeling to evaluate the advection of cold air masses over warm surfaces, similar to that described by Tillman et al. 1979. Segal, Arritt and Tillman state in their abstract: "The Martian daytime soil surface temperature is governed primarily by the net irradiance balance and the surface soil heat flux. Thus outbreak of a cold air mass generates increased sensible heat flux which is conducive to daytime dissipation of the cold air mass thermal characteristics. Conceptual and scaling evaluations of this dissipation are provided while contribution to the dissipation of the original thermal structure of the cold air could be three times larger than the corresponding situation on Earth. Illustrative numerical model simulations provide scaling of the potential impact on the dissipation of cold air masses for various combinations of background wind speeds and latitudes." This note has been accepted for publication by the Journal of Atmospheric Sciences and is included here.

2.0 Pathfinder landing site Model and Viking wind estimates

Winds at potential Pathfinder locations were estimated from model runs and Viking data to support of site selection. These Viking planetary boundary layer observations and models inferences, were presented at the Pathfinder site selection meeting at JPL 9,10 June 1994. Prior to this meeting, Ames models implied higher winds closer to the equator, which seemed to be inconsistent with other modeling. At the landing season, $L_s = 145°$, an optical depth, $\tau = 0.4$ from Viking Lander 1 data, was chosen as representative of this latitude and Segal performed model calculations. Heat flux and wind speed (at 1.6 meters and versus height) and potential temperature, were calculated as a function of: 1) z_0 and geostrophic wind, 2) height and geostrophic wind, and 3) height and z_0, for four times of day for a flat site. The same calculations were performed for a sloping terrain between two level sites to simulate the slope winds of the Chryse basin using both zero and 5 meters/second geostrophic wind speed.

Tillman showed that the Viking Lander 1 hourly mean wind speed was a maximum of 12.2 meters/second at the 1.5 meter sensor height, during the same season. Assuming that its slope is greater than that of the Pathfinder prospective sites, the Pathfinder winds would be similar or less, based only on this information, which is consistent with Segal's calculations.

These results were presented at the Second Mars Pathfinder Project Science Group Meeting, JPL, 9-10 June, 1994 by Tillman, and are contained in the meeting notes, pages 198 - 242.

3.0 Investigation of Lander 2 inter-annual temperature differences

Analyses of the Viking Lander 2 sol minimum, mean and maximum temperatures by Tillman showed that the minimum and mean temperatures were the same during summer of the first and second year. However, the maximum temperature for the first year was consistently $5° K$ colder than during the second year. The first obvious parameter to examine, optical depth, differs very little and in the wrong direction. Segal and Arritt carried out multiple 1-D simulations showing that the next most important parameter was wind speed but the Viking data have very small inter-annual differences, even changing signs during the summer. Finally Segal and Arritt, showed that the effects of small changes in surface albedo and deep soil temperature were even less important.

The data remain a puzzle and these results will be published along with the observations and more complete analyses in a subsequent paper.

4.0 Convert Viking surface temperature estimation software

Determination of the surface temperature was a key component of the PBL analyses of Tillman Landberg and Larsen: estimates were made using algorithms developed by Ronnholm and Leovy, for Viking data analyses. These have been separated from the Viking software, SANMET, checked out as a stand alone Prime program, moved to the Unix systems and verified. The surface temperatures and radiative fluxes for the TLL sols were provided to Segal and Arritt for comparison with the model calculations. The algorithms can be made available for general use, including the parameters developed for the two Viking sites during the mission.

5.0 Related work

Tillman is a member of the ASI/MET Science Advisory Team and has applied to participate in the mission. He was heavily involved in the development and analyses of the meteorology sensors, especially the wind sensor, and in mission scenarios. He collaborated in the development of the Mars 96 program with colleagues at the Finnish and Russian Space Science Institutes in the areas of instruments and science, development and testing.

3) Reports and publications

Manuscripts,

Segal, M., R. W. Arritt, and J. E. Tillman, "On the potential impact of daytime surface sensible heat flux on the dissipation of Martian cold air outbreaks", accepted J. Atmos. Science, Sept. 1996.

References

Tillman, J. E., R. M. Henry and S. L. Hess,
Frontal Systems During Passage of the Martian North Polar Hood Over the Viking Lander 2 Site Prior to the First 1977 Dust Storm, J. Geophys. Res., 84, B6, pp 2947-2955, 1979.

Tillman, James E., Lars Landberg and Søren E. Larsen,
"The Boundary Layer of Mars: Fluxes, Stability, Turbulent Spectra and Growth of the Mixed Layer." J. Atmos. Sci., June 1994, 51, p 1709–1727.

Related reports and papers presented at meetings, workshops,

Tillman, J. E.
Viking lander 1 meteorological data and modeling. Second Mars Pathfinder Project Science Group Meeting notes, pp 198 -242, for Landing Site Selection, 9,10 June, 1994

Segal, Moti
Atmospheric simulations for Pathfinder landing season and latitude. Second Mars Pathfinder Project Science Group Meeting, Landing Site Selection Group, 9,10 June, 1994

Papers; partially supported by this grant

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The Boundary layer of Mars: Fluxes, stability, Turbulent spectra and the growth of the mixed layer. Risoe-Report R- 701 (EN), 54 pages, 1995.

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"The Boundary Layer of Mars: Fluxes, Stability, Turbulent Spectra and Growth of the Mixed Layer." J. Atmos. Sci., June 1994, 51, p 1709–1727.